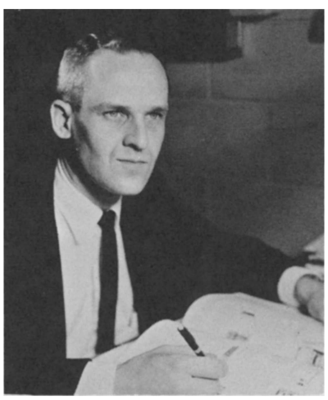
# AUTHORS AND PAPERS

The highly condensed summaries of papers and technical notes (below) are intended to assist the busy reader in determining the order in which to read the technical material. Biographical comments are for human interest.

## CRITICAL DIMENSIONS OF $^{235}U$-$H_2O$-Zr

A quantitative determination of the extrapolation distances for water-reflected homogeneous systems of $^{235}U$-$H_2O$ and $^{235}U$-$H_2O$-Zr has been achieved utilizing, in a unique manner, nuclear codes with the results agreeing well with available experimental data. A reactivity-composition-buckling (RCB) diagram containing extrapolation distance and critical buckling as a function of composition for this ternary system has been developed that permits the determination of the optimum conditions for criticality as well as the critical dimensions for a given shape and composition.

*C. H. Price, G. P. Rutledge, and F. A. Dobbe, shown left to right, are members of the Westinghouse Electric Corporation, Bettis Atomic Power Laboratory, located at the Naval Reactors Facility near Idaho Falls, Idaho. Rutledge, Supervisor of S1W Analysis and Test, started his nuclear career with the Manhattan Project in Oak Ridge in 1945 and joined Bettis in 1956. Price, Criticality Control Standards Supervisor, became affiliated with Westinghouse in 1955. Dobbe, senior test engineer, joined Westinghouse in Kansas City in 1955 and transferred to Bettis in 1960. All three authors have contributed to the nuclear safety of the prototype power plants and fuel handling activities of Bettis Laboratory in addition to their testing and training responsibilities.*

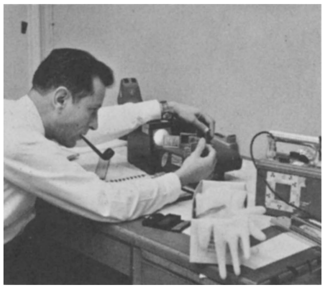


## NEUTRON RADIOGRAPHY

Using a pool reactor core as a neutron source and the water as a biological shield, radioactive material may be examined by neutron radiography techniques. Representative radiographs of clad fuel rods up to 1.2-m in length and stainless-steel capsules up to 2.9-cm in diam and 60-cm long are presented in this work.

*Wayne A. Carbiener joined Battelle in 1962 as a member of the Battelle Research Reactor staff. In that capacity, he has participated in the design and operation of a variety of reactor associated experiments. During the past year, he has been responsible for the development of the neutron radiographic technique and apparatus employed at Battelle. He is a graduate of Purdue University, having obtained degrees in Mechanical and Nuclear Engineering, and served in the US Navy prior to joining Battelle.*

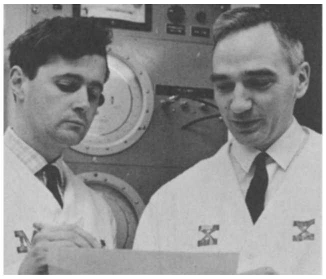
## $^{235}UO_2$ THIN FILM DEPOSITION



Thin films of enriched $UO_2$ have been deposited on stainless-steel sheet by vacuum vapor deposition, using an electron gun to vaporize the $UO_2$. This description of the development of a known technique, used in the study of energy deposition efficiency by fission fragment escape, resulted in curves for rate of deposition and uniformity of thickness as well as an experimentally derived formula which relates deposition parameters to uniformity of thickness.

*R. M. Baciarelli (BSME Instituto Tecnico Industriale, Italy and BS, Physics and Math, Sacramento State College, 1960) joined Aerojet in 1960 and is now a senior physicist in the Applied Science Division, where he has been working primarily in the field of nuclear reactors technology and vacuum deposition of thin films of radioactive materials for fission-fragment energy studies. He has conducted a neutron irradiation program on $UO_2$-$NH_3$ slurries and performed component development and testing for the hydrazine program in-reactor loop and he is co-author of two patents pending.*

## STEPWISE RELEASE OF FISSION GAS



Measurements of the fission-product gas pressure in $UO_2$ fuel elements during irradiation have shown that a significant amount of gas is released during power transients. The gas appears to be released as the element power is decreased to zero during reactor shutdown, little release occurring as the power is raised at startup. It is postulated that gas trapped in bubbles or in a central void is released by cracking or stress-induced movement during the power transient.

*M. J. F. Notley (left in the photograph) works in the Reactor Materials Branch at Atomic Energy of Canada Limited, where he has been concerned with the design and analysis of in-reactor experiments on fuel element performance. J. R. MacEwan, a Group Leader in the Branch, is best known for his work on grain growth and diffusional gas release from nuclear ceramics.*

## CREEP-RUPTURE PROPERTIES

Creep behavior of several refractory alloys under a linearly increasing stress has been successfully predicted from creep data at constant stress, using the analytical model developed in this work. The model does not apply equally well to all materials and it is necessary to perform limited tests to determine its applicability to a given material.

*H. E. McCoy (PhD, Metallurgical Engineering, University of Tennessee, 1964) has been employed as a metallurgist at Oak Ridge National Laboratory since 1958. During the last two years, he has also been a part-time staff member of the engineering college at the University of Tennessee.*

## RADIATION DAMAGE IN INCOLOY–800

After irradiation in either thermal-fast or fast-neutron spectrums, Incoloy-800 was observed to have a general decrease in elevated-temperature postirradiation ductility. The observed embrittlement was more dependent on postirradiation test temperature than on irradiation temperature.

*The authors, while members of the Superheat Fuels and Materials Development Unit at the General Electric Vallecitos Atomic Laboratory, are primarily engaged in development of fuel for high-temperature steam-cooled reactors. Dr. C. N. Spalaris (shown in center), Unit Manager, has been active in both steam-cooled and boiling-water reactor fuels for the past ten years. Both F. Comprelli (shown at right) and H. Busboom have major interests in material-evaluation and radiation-damage studies as related to high-temperature fuels. Presently, Comprelli is Manager of the Fast Reactor Metallurgy Unit and engaged in development of suitable system materials for fast ceramic reactors.*

## UTILITY NUCLEAR FUEL REQUIREMENTS

The utility-oriented view of fuel performance requirements for water reactors recognizes nuclear fuel as high-precision equipment with complex lifetime characteristics and very high capital value. The relatively long energy extraction time,

energy variations between core areas, necessity for fuel management, increased complexity of fuel design and procurement, and large degree of government control over fuel are cited as considerations the utility user of reactors must bear in mind in choosing nuclear fuel.

*John E. Gray has been President of the NUS Corporation (formerly Nuclear Utility Services, Inc.) since its organization in 1960. Before that he served as Duquesne Light Company's Project Manager for the Shippingport Atomic Power Station. Prior experience in the atomic energy field included nuclear materials development work with Westinghouse Electric Corporation in the early stages of the Manhattan Project and with General Electric Company, fuel development in support of the design of the first naval nuclear propulsion reactors (with the Naval Reactors Branch of the USAEC), and the position as Technical Director for the USAEC during design and construction of the Savannah River Plant.*

## PWR FUEL EXPERIENCE

Excellent results have been obtained from irradiating fuel elements in pressurized-water reactors. Over 250 000 fuel elements containing $UO_2$, $UO_2$-$ThO_2$, or $UO_2$-$PuO_2$ fuel clad with iron- or zirconium-base alloys have performed reliably over a broad range of operating conditions. The obtained data indicate that limits for successful performance of PWR fuel elements have not been reached.

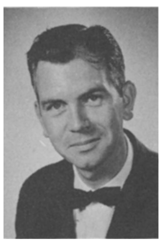
*R. J. Allio and H. M. Ferrari, shown left to right, are members of the Engineering Department, Westinghouse Nuclear Fuel Division (an affiliation of the Westinghouse Atomic Power Division). Dr. Allio joined WNFD in 1962 after holding various positions with the USAEC and KAPL. He performed his graduate work at Rensselaer Polytechnic Institute. He presently serves as Engineering Manager. Dr. Ferrari joined the WNFD in 1958 after graduate work at the University of Michigan. He presently serves as Manager, Radiation Effects.*

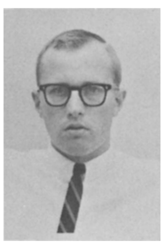
## BLANKET FUEL AND CLADDING IN PWR-1

High-density $UO_2$ fuel pellets in blanket rods of the first Shippingport core show no structural change after depletions to $6.4 \times 10^{20}$ fissions/cm$^3$. After 1885 days in hot water, corresponding to post-transition corrosion conditions, the Zircaloy-2 tubing shows a mottled appearance and an oxide thickness averaging 2.4 μm, predictable from out-of-pile autoclave testing.

*Along with their irradiation testing of plate-type elements and rods with various oxide fuels, L. Lynam (shown at left) and B. Rubin have examined natural-$UO_2$ fuel rods removed from the blanket region of the first core of the Shippingport Reactor during the replacement of each of the four metallic-fueled seeds. Both metallurgists, L. Lynam is a Carnegie Tech graduate while B. Rubin in a Penn State graduate with an MS degree from the University of Pittsburgh.*

## CANDU FUEL PERFORMANCE IN NPD

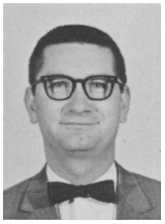




Over 1500 fuel bundles have been irradiated in the NPD, with burnups and residence times exceeding 10 000 MWd/t and 850 days, respectively. Most of this fuel was sheathed with thin collapsible sheathing. Deuterium picked up by the Zircaloy-2 sheathing from the heavy-water coolant has not affected fuel performance. Dimensional changes and fission-gas release were very small, and a defected bundle showed little or no deterioration after two and one-half years of operation.

*Geoffrey H. Chalder received his bachelor's degree in Metallurgy in 1951 from Durham University, England. From 1951 to 1955, he was employed by the UKAEA at their Culcheth Laboratories. Since 1955, he has been at Chalk River Laboratories of AECL, where he is presently responsible for the development of CANDU-PHW fuels. John Pawliw received his bachelor's and master's degrees in Chemical Engineering from the University of Saskatchewan. Since 1956, he has been with the Atomic Power Department of Canadian General Electric; at present he is Manager of Fuel Engineering. Robert T. Popple received his BSc from Queen's in 1963 in Engineering Physics, and since that time spent two years as a reactor physicist at NRU. At the time this paper was written, he was attached to CRNL as a liaison officer employed by Ontario Hydro for work on an alternate fuel for Douglas Point, and was in charge of the cell examination of fuel removed from NPD.*

## BWR FUEL PEFORMANCE


Based on the highly successful performance of many thousands of fuel segments operating at typical commercial power-reactor thermal ratings, $UO_2$ rods clad with Zircaloy-2 have proven to be the most reliable and economical fuel elements for boiling-water reactor applications, according to the material presented in this paper.

*T. J. Pashos, H. E. Williamson, and R. N. Duncan, affiliated with the General Electric Company's Nuclear Energy Division, San Jose, California, have been key contributors for several years in the development of fuel elements for General Electric's boiling water reactors. Currently, Pashos is Manager, Reactor Development Applications in the Nuclear Technology Department, Williamson is Manager, Fuel Engineering in the Atomic Power Equipment Department, and R. N. Duncan is a Technical Leader in the Fuels Development and Design Materials Unit in the Nuclear Technology Department.*

## DATA-ACQUISITION SYSTEM RESOLVING TIME

In making pulsed-neutron source measurements, counting rates of such magnitude are often encountered that the characteristics of the data-acquisition system must be properly identified before corrections for coincidence losses can be accurately made. To account properly for coincidence losses at very high counting rates, it is necessary to determine how closely a perfectly paralyzable or completely non-paralyzable system represents the real detection system used in the measurements. A "maximum observed counting rate" technique is presented which, in conjunction with a double-pulse method, permits the system to be characterized relative to these two theoretically limiting models.

*S. R. Bierman, Senior Experimenter at the Critical Mass Laboratory of Battelle-Northwest, K. L. Garlid (standing), Associate Professor of Nuclear Engineering and Chemical Engineering at the University of Washington, and J. R. Clark, Instrument Engineer, formerly with Battelle-Northwest, have been involved with neutron kinetic studies for the past few years. They have worked as a team at the Critical Mass Laboratory, to which Garlid is a consultant. Although the primary emphasis to date has been on clean, well-defined plutonium-fueled assemblies, the investigations are oriented toward reactivity measurements on poorly defined multiplying systems and the study of neutron behavior in reflected systems. Clark (BSEE, University of Arizona, 1962), currently with The Boeing Company, Seattle, Washington, is not shown.*

## SNAP-8 REACTOR COOLANT ANALYSIS

Radiochemical and spectrochemical analyses of short-cooled samples of SNAP-8 Experimental Reactor primary coolant revealed essentially no detectable corrosion-product activities in the NaK. Fission-product $^{137}Cs$ was clearly observed. Spectrum stripping techniques revealed no fission products in the coolant except $^{137}Cs$, $^{131}I$, $^{132}Te$, $^{132}I$, and $^{125}Sb$. Corrosion-product and fission-product activities were observed on primary cold trap and piping surfaces.

*Knox Broom (not shown), Carleton Bingham (shown at left), Tom Crockett (shown at right), and Nancy Trahey are members of the Analytical Chemistry Unit of the Reactor Chemistry Group which is responsible for radiochemical, spectrochemical, and wet chemical research and support at Atomics International. Bingham (PhD, Physical chemistry, UCLA) joined AI in 1959 and is currently Supervisor of Analytical Chemistry. Broom (PhD, Nuclear and Radiochemistry, University of Arkansas) joined AI in 1963 as a Senior Research Chemist. He is now with the Fuels and Materials Branch, Division of Reactor Development and Technology, USAEC. Crockett (AB, Auburn) and Miss Trahey (AB, Immaculate Heart, Los Angeles) are Research Chemists with specialties in radiochemistry and radiochemical measurements.*